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CRYSTAL PRODUCTS DEPARTMENT

LINDE COMPANY

Division of Union Carbide Corporation

30 East 42nd Street

New York 17, N. Y.

Declassified in Part - Sanitized Copy Approved for Release 2012/04/11 : CIA-RDP78-03535A000600100004-9

Name ....

Company.. Title.......................................

Address ....

☐ We would like further information on LINDE industrial crystals.

☐ We would like your representative to call.

We have the following applications in mind.

....

....

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Printed in U.S.A. F-1046

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LINDE COMPANY • DIVISION OF UNION CARBIDE CORPORATION

30 EAST 42ND STREET, NEW YORK 17, N. Y.

June 5, 1958

[redacted] 25X1

Dear [redacted] 25X1

Thank you very much for your recent inquiry about Linde sapphire. Linde industrial sapphire is transparent, has good dielectric characteristics, a high melting point, high strength at elevated temperatures, and extreme hardness. In addition, <u>industrial sapphire is a non-porous, single crystal of pure aluminum oxide</u> -- it is not a sintered product. Consequently, sapphire does not give rise to outgassing problems. This new material is available in the form of windows, rods, balls, tubing, and special shapes. It can be cut, polished, shaped, and sealed to metals, glasses, and ceramics by standard techniques.

Linde sapphire is being used as windows for high power klystrons, magnetrons, traveling wave and TR Tubes. In applications, such as tube element supports, spacers, and tuning slugs, where outgassing has been a source of trouble, industrial sapphire is particularly valuable. It is also employed in infra-red and ultra-violet devices because of its desirable transmission characteristics at elevated temperatures (500°C and up).

We have attached some technical literature which we hope will prove of interest to you. Should you desire additional data or in case you wish to discuss a particular problem in greater detail, please do not hesitate to contact us.

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Very truly yours,

LINDE COMPANY

S. Hahn

S. Hahn
Flame-Plating and Crystal Products Dept.

S.Hahn
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att./11

CO

Synthetic Sapphires, Lodge Ring Favorites, Aid Industry, Medicine

By Sidney B. Self

Staff Reporter of The Wall Street Journal

Reprinted from "THE WALL STREET JOURNAL" September 18, 1956

Man-Made Gems Help Guide Missiles, Analyze Liquids, Measure Temperatures

NEW YORK—Synthetic sapphires, until recently gleaming only in fraternal and lodge rings, now are going into guided missiles, industrial automation gadgets and medical equipment.

The fast-spreading use of these man-made gems stems from two factors—their long-known ability to transmit infra red rays and the recent development by Linde Air Products of a method of making large size clear white sapphires. Linde, a division of Union Carbide & Carbon Corp., has succeeded in making "windows" of synthetic sapphire three inches in diameter; company technicians hope before long to produce transparent sapphires six inches across.

Actually, it is the singular characteristics of infra red rays—often referred to as heat rays—that make synthetic sapphires so useful. Any warm object, from an aircraft engine to a human body, gives off infra red rays, which can be detected, measured and analyzed by various instruments. Sapphire, however, is one of the few substances which will transmit these infra red rays through to measuring instruments. Gem sapphires, of course, are too costly, and often too small, for industrial use. But one-inch synthetic sapphire windows cost as little as $15, making them cheap enough for wide use.

Guiding Guided Missiles

Because infra red rays can be detected with such precision, instruments utilizing sapphires can guide an anti-aircraft guided missile to its target—by "homing" on the heat given off by the airplane's motors.

Similar devices can be used to spot aircraft flying overhead, tanks hidden in the woods or even troops masked by darkness or fog. And infra red has a great advantage over radar; it can't be jammed by natural or man-made electronic storms. Because infra red detection devices can't be jammed, there have been proposals to set up an infra red airplane detection system to augment the radar fences now guarding the United States and Canada.

Industrial uses of infra red, and synthetic sapphires, are based on the same general principles as military applications. Just as infra red rays given off by a plane or a person are so individually varied that they can be caught in a photograph, organic chemicals and gases generate infra red rays of different wave lengths and as identifying as fingerprints.

Instruments already in use can instantaneously analyze chemicals flowing through a pipe by measuring infra red rays. This is done by putting a pair of synthetic sapphire windows in the pipe, and a heat source on one side. Infra red rays are passed to an electric system that provides an analysis of the flowing chemical with an accuracy that could be duplicated by human chemists only after hours of laboratory work.

Making Process Automatic

By connecting such measuring devices to valves and other production controls, any variation in the composition of a flowing liquid, as in a chemical plant, can be detected and corrected automatically. One such device installed by Lion Oil Co. in a synthetic ammonia plant increased production to 150 tons from 100 tons daily because of increased accuracy of control. Union Carbide employs such an instrument at its Charleston, W. Va., petro-chemical plant and American Cyanamid is using one, made by Perkin Elmer, at a Fortier, La., plant.

Medical men also use infra red instruments with synthetic sapphire windows to analyze gases. In breathing, carbon dioxide gas is exhaled; a change in the amount of carbon dioxide may indicate a person needs more oxygen. Instruments can analyze the breath of a patient under anesthetic on an operating table, for instance, to tell quickly whether more oxygen should be administered. Such breath-measuring devices are so sensitive they can determine whether a person lives in a city or rural area, and whether he smokes.

Another major industrial use of man-made sapphires is in "light pipes"—rods up to 20 inches long used to measure very high temperatures accurately. These rods, which will stand temperatures up to 3,500 degrees Fahrenheit, can be put through the wall of a steel furnace to transmit heat to an electrical device that actually measures the temperature. Such rods are used in furnaces that "grow" germanium and silicon crystals for transistors. In this delicate process, temperatures of 1,000 to 1,500 degrees often must be measured within one-half of one degree. Similar rods are expected to be used for heat measurement and control in jet planes.

Synthetic sapphire production is a difficult task that starts by dropping fine particles of aluminum oxide onto a small pedestal in a furnace. These droplets solidify or "freeze" as they hit the cooler part of the furnace; as more droplets solidify, crystals build up like stalagmites in a cave. The process creates what is called a boule, about the size and shape of a man's thumb, which can be split into synthetic gems. Long, even round rods also can be produced and sawed into jewels, or oversize boules can be created for splitting into the three-inch sapphire windows. Only a few dozen windows of such size have been produced so far: they sell for $150 each.

Synthetic sapphires were first made around 1910 by a Frenchman named Verneuil, who was trying to make rubies. (Rubies are a form of sapphires containing a bit of chrome, which gives them their characteristic red color. Real sapphires are one of the four true precious stones, along with rubies, diamonds and emeralds. In ancient folklore; the sapphire was the April birthstone. Today, however, it is the birthstone of September.)

The first general use of synthetic jewels, including sapphires, was in watches. A shortage of such jewels for watches and precision instruments in World War II first drew Linde into production of crystals of the synthetic gem type. After the war, Linde sold synthetic sapphires and rubies for jewelry, but almost abandoned this field due to low-priced competition from German synthetic gem makers. Now 85% of Linde's gem business is in industrial, military and medical stones.

Linde Trade-Mark

Industrial Crystals
BULLETIN

No. 3

Properties of Industrial Sapphire

DATE 12/18/56

LINDE sapphire is available in the form of windows, rods, tubing, boules, and special shapes. It is used as supports and spacers for vacuum-tube and microwave apparatus, as windows for klystrons and magnetrons, and as components for various ultra-violet and infra-red devices. Some of the characteristics of this single-crystal non-porous material are outlined below.

Composition . . . . 100% aluminum oxide (Al_2O_3)

Crystal Structure . . . . Hexagonal (Single crystal, not a sintered product)

Finish . . . . Optically clear or frosted

Melting Point . . . . 2040° C

Hardness . . . . Knoop: 1525 to 2000
Mohs: 9

Specific Gravity 3.98

Specific Heat . . . . 0.18 calories per gram at 20°C

Porosity 0%

Chemical Resistance . . . . . . Practically inert to most reagents at room temperature. Inert to a large variety of reagents even at high temperatures (over 1000°C).

Thermal Conductivity . . . . . . 0.065 calories per centimeter squared per second per degree Centigrade per centimeter at 100°C.

Thermal Expansion . . . .

Mean Linear Expansion Coefficient
(Per degree Centigrade from 20° to various temperatures)

Temperature	Parallel to C-Axis	Perpendicular to C-Axis
50°C	6.66×10^{-6}	5.0×10^{-6}
500°C	8.33×10^{-6}	7.70×10^{-6}
1000°C	9.03×10^{-6}	8.31×10^{-6}

Electrical Resistance . . . .

500°C	1000°C	1500°C
10^{11} ohm-cm	10^{6} ohm-cm	10^{4} ohm-cm

Dielectric Constant and Power Factor (Loss Tangent) . . . . . .

	Field Parallel to C-Axis		Field Perpendicular to C-Axis	
Frequency (megacycles)	Dielectric Constant	Loss Tangent	Dielectric Constant	Loss Tangent
300	10.6	<0.0001	8.6	<0.0001
10,000	–	–	11.0	0.0002

Dielectric Strength . . . . Approximately the same as sintered aluminum oxide, which is: 480,000 volts per centimeter

Optical Transmission . . . . . .

Ultra-Violet (Sample 2mm. thick)	Infra-Red (Sample 1 mm thick)
66% at 2000 Angstrom	92% at 3 microns
20% at 1500 Angstrom	50% at 6 microns

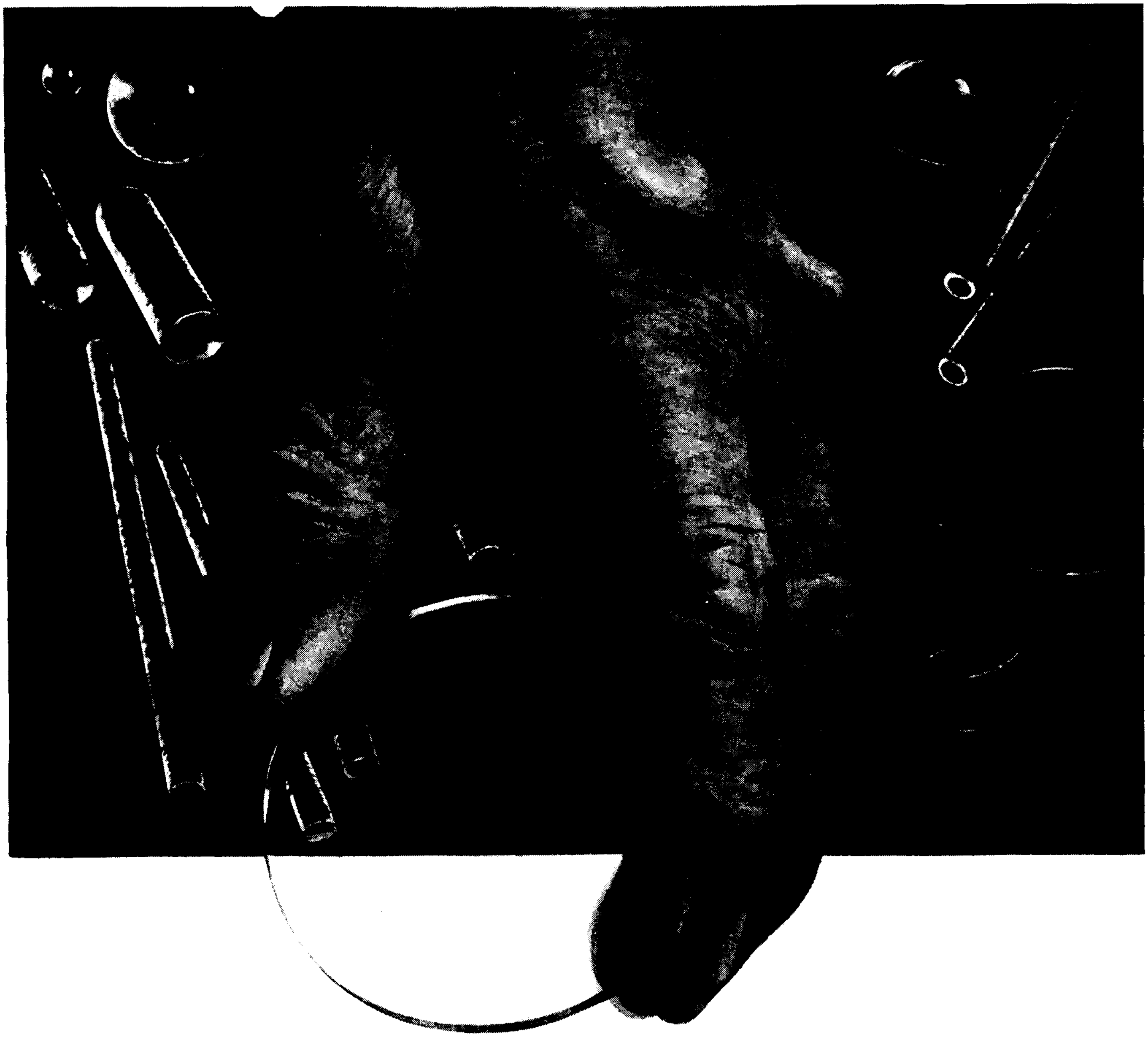
Compressive Strength . . . . . . 300,000 psi at 77°F

Young's Modulus . . . . 50 to 55×10^6 psi (Dependent on position of crystal C-axis)

Modulus of Rupture . . . . 30° C–40 to 130,000 psi
540°C–23,000 to 50,000 psi

Sealing Characteristics . . . . . High and low temperature seals can be made to metals, glass, and ceramics.

Linde Company
Division of Union Carbide Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities



LINDE SAPPHIRE...

SHAPED TO YOUR NEEDS

Single-crystal sapphire is produced by LINDE in many shapes for a wide variety of applications. Common shapes include windows, balls, rods, and tubes. Special shapes are supplied to order.

LINDE sapphire is transparent, non-porous, and has excellent ultra-violet and infra-red transmission characteristics. Infra-red transmission is 92% at 3 microns, 50% at 6 microns (1 mm thickness). Typical uses are as windows, spacers, and supports in electronic tubes; for light pipes; and for ultra-violet and infra-red devices. High- and low-temperature seals can be made to metals as well as to glass and ceramics. Inquiries regarding mechanical, optical, thermal, and electrical properties of LINDE sapphire are invited. Write Crystal Products Dept.

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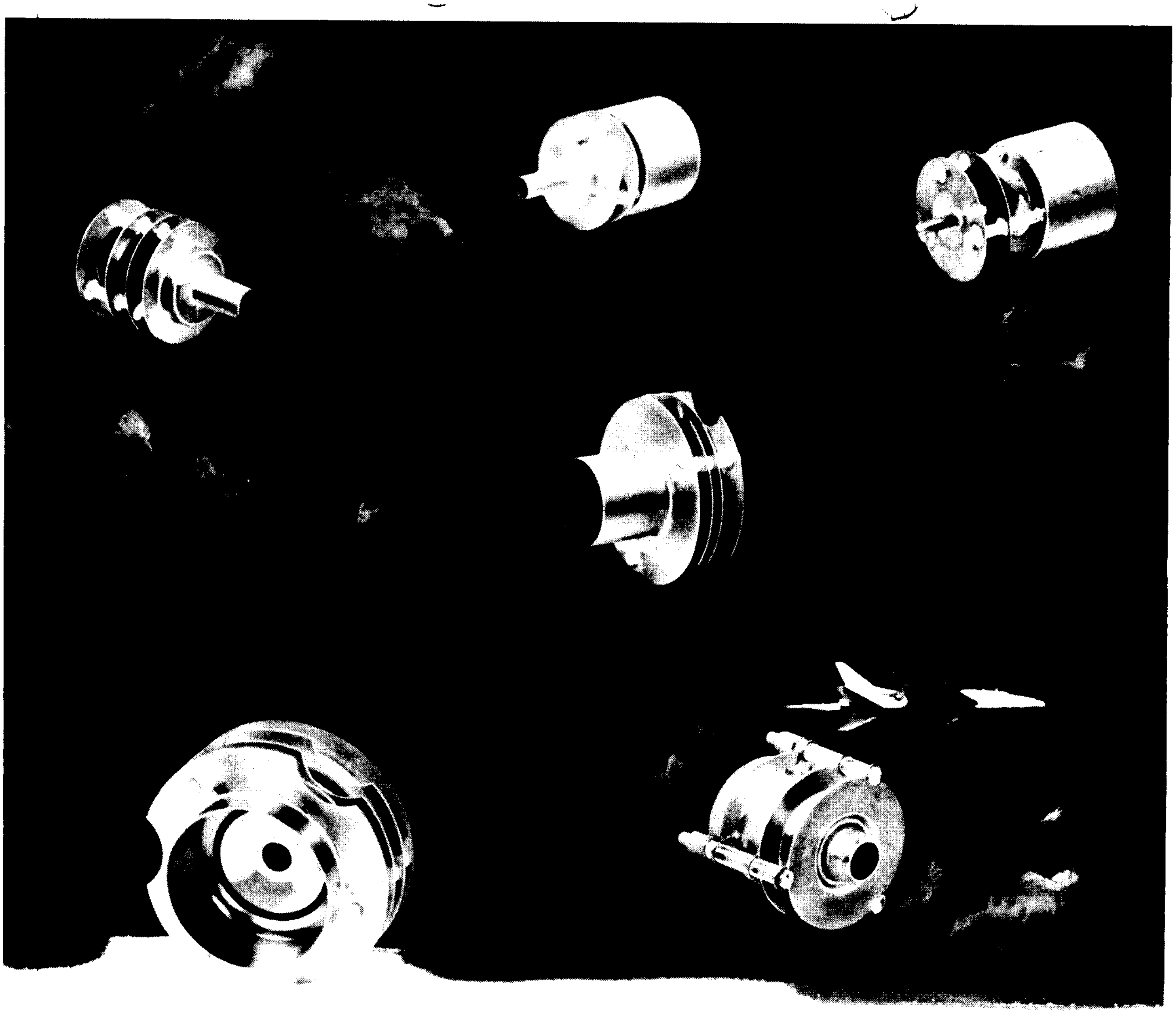
LINDE COMPANY

Division of Union Carbide Corporation

30 East 42nd Street UCC New York 17, New York



WHERE RUGGEDNESS COUNTS...

LINDE SAPPHIRE SPACERS

FOR ELECTRON GUN STRUCTURES

Among the fine products of Sylvania Electric Products Inc. are high-quality traveling wave tubes for airborne equipment. In these tubes, electron gun structures are built with LINDE single-crystal sapphire rods—selected by Sylvania because of their ruggedness, needed for this application.

LINDE sapphire rod can be supplied to close tolerances, providing for precise alignment of parts and making quantity production of identical units possible. It is easily brazed and metallized. LINDE sapphire is non-porous ... presents no outgassing problems. Assemblies made with it are rugged . . . stand up under adverse conditions such as shock and vibration.

LINDE sapphire is also available as tubes, balls, windows, and domes, and in special shapes. It has strength at high temperatures, and excellent ultra-violet and infra-red transmission characteristics. Detailed information on physical and electrical properties of LINDE sapphire is your for the asking. Please write to "Crystal Products Dept."

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30 East 42nd Street UCC New York 17, New York

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PROPERTIES AND USES OF LINDE SAPPHIRE

The art of manufacturing single crystal alumina (sapphire) is relatively old; it dates back to the 1900's when Verneuil devised a method of making this material using a hydrogen-oxygen blowpipe through which very fine purified alumina powder was fed. This technique for growing single crystals of high melting point oxides (for example, sapphire melts at 2040° C.) is currently being used by the Linde Company in the production of single crystal alumina (sapphire).

Clear synthetic sapphire is a pure, single crystal alpha alumina (less than 100 ppm total impurities), while ruby and colored sapphires have doping materials such as chromium, titanium, iron, nickel or cobalt added. Thus, the term "synthetic sapphire" can be used for both the clear variety made of pure aluminum oxide powder and the colored varieties made of doped aluminum oxide powder.

The Verneuil process consists of slowly and intermittently dropping fine powdered alumina through a post-mixed oxy-hydrogen flame on to a molten cap of a seed crystal as shown in Figure 1. A temperature gradient is maintained in the growing crystal so that as additional material is fed on to the molten cap "freezing out" occurs at the interface between the body of the crystal and the molten cap. The growing crystal is then lowered maintaining the molten cap in the same region of the flame. If proper conditions are maintained, the material which freezes out will have the same orientation as the seed crystal and large crystals are slowly formed. The as-grown crystal is highly strained and must be annealed at temperatures over 1900° C. before the whole piece can be fabricated without cracking.

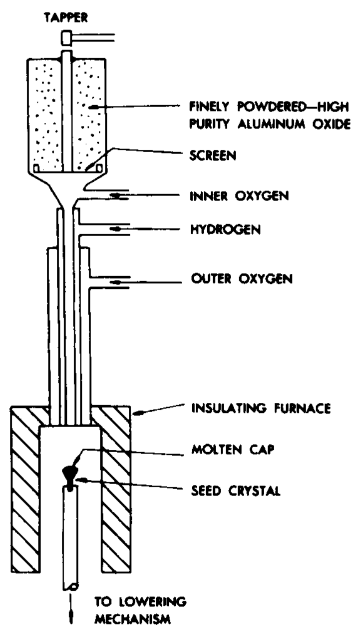

Fig. 1. Growing Sapphire by the Verneuil Technique

Fig. 2. Some Typical Sapphire Shapes

Linde improved the original Verneuil growth process to such a degree that it is now possible to produce large sapphire disks up to 5½ inches in diameter, domes and hemispheres, rods, slugs and many special shapes. Some typical as-grown and finished sapphire pieces are shown in Figure 2.

The applications of sapphire are many and diversified. Many depend on properties specific to the unicrystallinity of sapphire and its inherent purity. For wear-resistant applications, the material is unique. Its extreme hardness and ability to take an extremely smooth polish make it ideally suited for critical wear applications. It is used for wear guides in tape recorders, as thread guides in textile mills and camera film guides, it is an ideal bearing material in instruments, and it is the most frequently used material in phonograph needles.

Like sintered aluminum oxide, sapphire is an excellent insulator and is a low loss dielectric material from low frequencies up to the microwave region. As an insulator in vacuum systems, sapphire has the outstanding advantage over sintered alumina in that it has zero porosity and so it does not outgas. These properties of low dielectric losses, high resistivity, mechanical strength and freedom from outgassing problems make sapphire ideally suited for output windows for microwave tubes such as klystrons and magnetrons, internal supports for vacuum tubes, insulators, and low leakage capacitors.

In recent years sapphire has become a highly important material in the field of optics. The transmission of sapphire runs from the middle of the Schumann region (1450 angstroms) to the intermediate infrared region (6 to 7 microns). In addition, sapphire's usable transmission characteristics in the infrared region go up to 1500° C. Thus sapphire has a considerable potential in specialized optical applications: for example, the exterior window of military infrared equipment, missile domes, optical windows in high pressure or high temperature systems; lenses where its low dispersion and resistance to mechanical abrasion or scratching is needed; and in gaseous discharge lamps where its resistance to crazing

Linde Trade Mark

LINDE COMPANY

Division of Union Carbide Corporation

30 East 42nd Street UCC New York 17, New York

from the electrical discharge and its desirable ultraviolet transmission characteristics are required. Particularly interesting is the use of a sapphire rod as a radiation tube to bring infrared radiations from a heated target to a sensitive detector which can be placed in a cooler area.

It is quite evident that sapphire is widely being used in industrial, military and laboratory applications where unusual environmental conditions exist and where its special properties are needed. It is the very unique combination of these properties which make sapphire suitable for many applications where previously conventional materials fail or are short-lived. Sapphire will continue to be used more and more and will be accepted as a conventional special material in an increasing variety of applications.

METAL TO CERAMIC OR "LINDE" SAPPHIRE BONDING TECHNIQUES

MATERIALS	METALLIZER			SOLDER			BOND
	Material	Firing Temp.	Atmosphere	Material	Temp.	Atmosphere	
LINDE sapphire	TiH	1000° C	Vac	Ag	960° C	Vac	Good
	ZrH	1000° C	Vac	Ag	960° C	Vac	Good
	CbH	1000° C	Vac	Al	700° C	Vac	Good
	TaH	1000° C	Vac	Al	700° C	Vac	Good
	ZrH	1000° C	Dry N_2	Ag	960° C	Dry N_2	Good
	None	—	—	15% Zr-Ag alloy	960° C	Vac	Good
Alundum 1139 to Tantalum	ZrH	1000° C	Vac	Al	700° C	Vac	Good
Molybdenum	None	—	—	15% Zr-Ag alloy	?	Dry N_2	Good
Ceramic (Type unknown)	Molybdenum	1300° C	Semi-reducing	Ag on Ni surface	960° C	H_2	?
Ceramic (Type unknown)	TiH	1000° C	Vac	Powdered Cu	?	Vac	Good
Zircon (zirconium silicate)	Molybdenum	1350° C	H_2	Ag on Ni layer	1000° C	Vac	Good
Alumina to Tantalum	None	—	—	Ti cored BT solder	1040° C	H_2	Good
Alumina	None	—	—	15% Zr-Ag alloy	?	H_2	Good
Alumina	None	—	—	15% Mn-Ag	—	H_2	Good
Alumina A1-200	None	—	—	Ti cored BT solder	900° C	Vac	Good
LINDE sapphire to Molybdenum	20% Mn-Mo alloy	1050° C	H_2	Au-Ni eutectic	1050° C	H_2	Good

NOTE: Vacuum of 10^{-4} mm. Hg

Some Properties of Industrial Sapphire

LINDE sapphire is available in the form of windows, rods, tubing, boules, and special shapes. It is used as supports and spacers for vacuum-tube and microwave apparatus, as windows for klystrons and magnetrons, and as components for various ultra-violet and infra-red devices. Some of the characteristics of this single-crystal non-porous material are outlined below:

Composition .... 100% aluminum oxide (Al_2O_3)

Crystal Structure .... Hexagonal (Single crystal, not a sintered product)

Finish .... Optically clear or frosted

Melting Point .... 2040° C

Hardness .... Knoop: 1525 to 2000
Mohs: 9

Specific Gravity 3.98

Specific Heat .... 0.18 calories per gram at 20° C

Porosity 0%

Chemical Resistance .... Practically inert to most reagents at room temperature. Inert to a large variety of reagents even at high temperatures (over 1000° C).

Thermal Conductivity .... 0.065 calories per centimeter squared per second per degree Centigrade per centimeter at 100° C.

Thermal Expansion ....

Mean Linear Expansion Coefficient
(Per degree Centigrade from 20° to various temperatures)

Temperature	Parallel to C-Axis	Perpendicular to C-Axis
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500° C	8.33×10^{-6}	7.70×10^{-6}
1000° C	9.03×10^{-6}	8.31×10^{-6}

Electrical Resistance ....

500° C	1000° C	1500° C
10^{11} ohm-cm	10^{6} ohm-cm	10^{4} ohm-cm

Dielectric Constant and Power Factor (Loss Tangent) ....

	Field Parallel to C-Axis		Field Perpendicular to C-Axis	
Frequency (megacycles)	Dielectric Constant	Loss Tangent	Dielectric Constant	Loss Tangent
300	10.6	< 0.0001	8.6	< 0.0001
10,000	—	—	11.0	0.0002

Dielectric Strength .... Approximately the same as sintered aluminum oxide, which is: 480,000 volts per centimeter

Optical Transmission ....

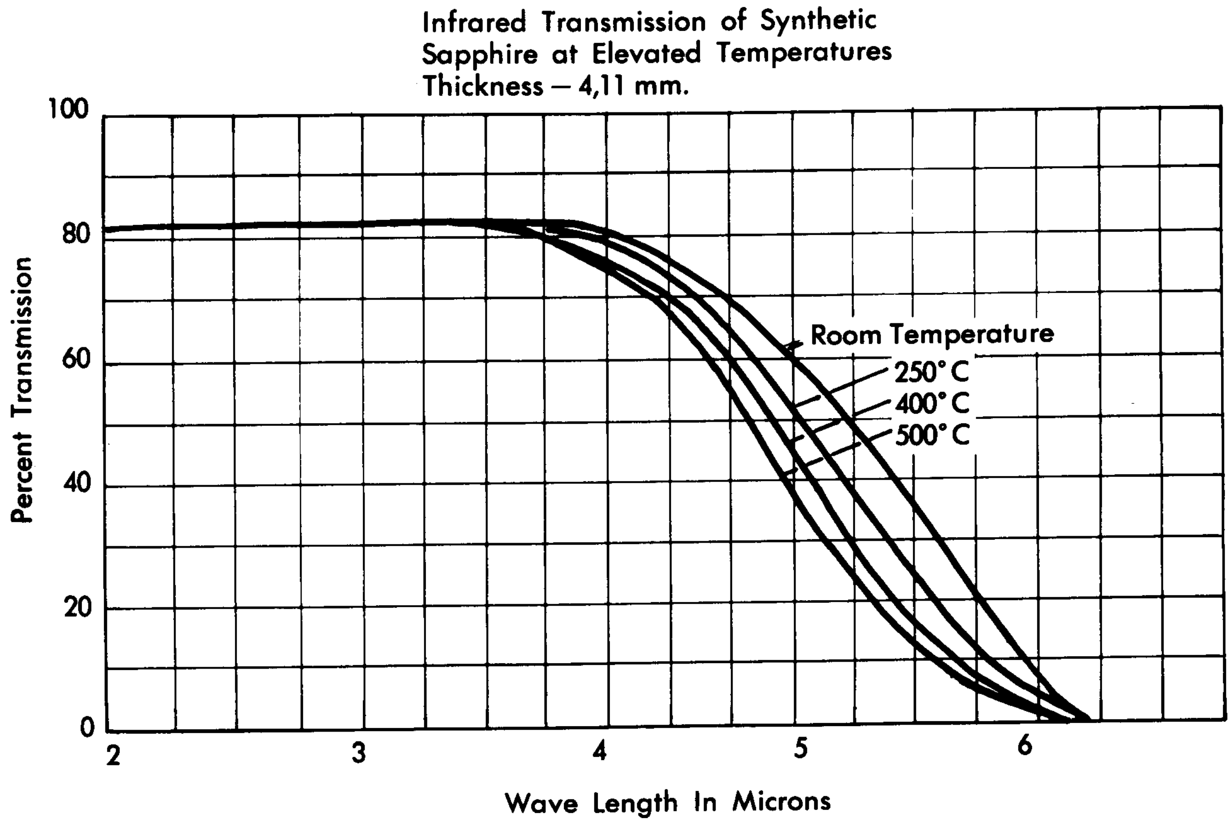
Ultra-Violet (Sample 2 mm. thick)	Infra-Red (Sample 1 mm. thick)
66% at 2000 Angstrom	92% at 3 microns
20% at 1500 Angstrom	50% at 6 microns

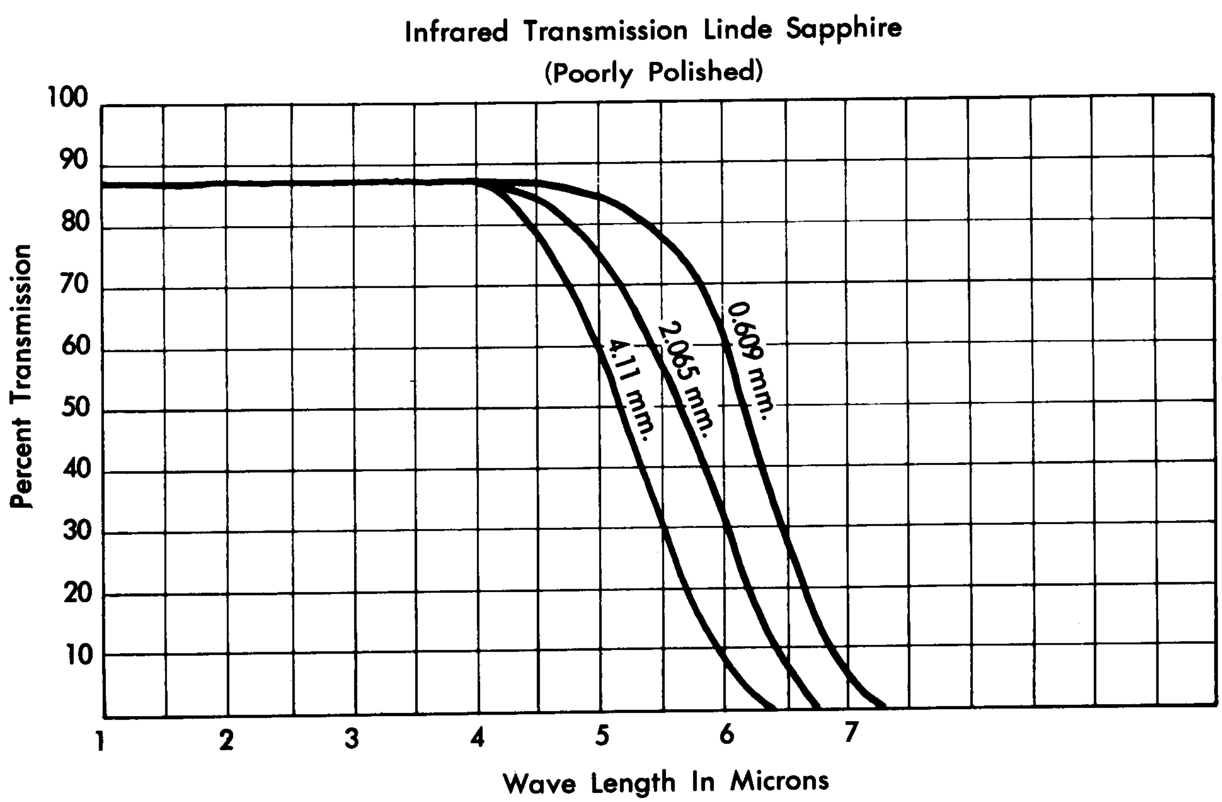
Compressive Strength .... 300,000 psi at 77° F

Young's Modulus .... 50 to 55 X 16^{6} psi (Dependent on position of crystal C-axis)

Modulus of Rupture .... 30° C—40 to 130,000 psi
540° C—23,000 to 50,000 psi

Sealing Characteristics .... High and low temperature seals can be made to metals, glass, and ceramics.


Infrared Transmission of Synthetic
Sapphire at Elevated Temperatures
Thickness — 4,11 mm.
100
80
60
40
20
0
Percent Transmission
Room Temperature
250° C
400° C
500° C
2
3
4
5
6
Wave Length In Microns


Infrared Transmission Linde Sapphire
(Poorly Polished)
100
90
80
70
60
50
40
30
20
10
Percent Transmission
0.609 mm.
2.065 mm.
4.11 mm.
1
2
3
4
5
6
7
Wave Length In Microns

F-1176